Effectiveness of the Saline Load Test in Diagnosis of Traumatic Elbow Arthrotomies

Todd Feathers, MD, Daniel Stinner, MD, Kevin Kirk, DO, Jess Kirby, MD, and Joseph R. Hsu, MD; Skeletal Trauma Research Consortium (STReC), Brooke Army Medical Center

Objectives: The purpose of this study was to investigate the amount of fluid required and the sensitivity of the saline load test to identify an intra-articular arthrotomy of the elbow.

Methods: A cadaveric study was conducted using 36 thawed, fresh-frozen forequarter amputations. An elbow arthrotomy was made in the posterocentral arthroscopic portal site with a 4.5-mm trochar. To confirm intra-articular location of the arthrotomy, the trochar was trapped in the ulnohumeral joint. The elbow joint was then loaded with saline mixed with methylene blue. During the injection, the known arthrotomy site was observed for leakage. If no leakage occurred after loading 20 mL of fluid, the elbow was taken through a range of motion. If still no leakage was appreciated at the arthrotomy site, the elbow was again infused with fluid in 2 mL increments until outflow. All injections were confirmed as intra-articular by demonstrating methylene blue staining of the anterior joint by open exploration.

Results: A positive result was obtained in 26 of the 36 elbows (72% sensitivity) with injection of 20 mL of fluid, and with the addition of range of motion, another 5 elbows demonstrated leakage, raising the sensitivity to 86%. However, to identify 95% of arthrotomies, a total of 40 mL of fluid had to be injected.

Conclusions: Our results demonstrate that 40 mL of fluid must be injected to identify the majority of traumatic arthrotomies about the elbow. Moreover, adding range of motion after the injection increases the detection rate.

Key Words: Saline load test, Periarticular elbow lacerations, Traumatic Arthrotomies.

(*J Trauma.* 2011;71: E110–E113)

Periarticular lacerations about the elbow are common injuries caused by various mechanisms, such as motor vehicle collisions, open periarticular fractures, fragments from combat explosions, and gunshot or stab wounds.[1] Joint penetration may be obvious with large open wounds, but it can be more difficult to determine with smaller wounds. Because of the risk of septic arthritis, identification of joint capsule violation necessitates a more extensive surgical treatment. Initially, the wound must be carefully examined with inspection and palpation looking for an effusion, hemarthrosis, or capsular defect.[2] Painful range of motion can also be a sign of joint involvement. Radiographs may reveal an effusion, retained foreign body, or air within the joint.[1] In addition, a saline load test may be used to help in diagnosis and determine whether or not to proceed with surgical intervention.[3]

The saline load test is performed by injecting sterile saline into a joint and then examining the joint for evidence of fluid leakage at rest and with passive movement. Fluid leakage from the joint indicates a positive test. A negative test is distention of the joint without evidence of leakage to the point of increasing resistance or patient discomfort.[4,5] Methylene blue can be added to the saline, based on surgeon preference, to make the diagnosis more clear.[4,6]

There is limited evidence in the literature about the effectiveness of the saline load test in the elbow or the fluid volume required for elbow injection.[4,5,7–10] Some authors suggest the use of 20 mL when performing a saline load test of the elbow.[9,10] The purpose of this study was to investigate the amount of fluid required and the sensitivity of the saline load test to identify an intra-articular arthrotomy of the elbow. We hypothesized that injecting 20 mL of saline and taking the elbow through a range of motion would detect 95% of known arthrotomies.

MATERIALS AND METHODS

Before conducting our investigation, the study was approved by our institutional review board. Using PASS 8.0.5 (Kaysville, UT), an N size of 30 is needed to achieve a power of 0.8 with an alpha of 0.05 to produce a two-sided 95% confidence interval with a width equal to 0.2 when the sample proportion is 0.950. Forty thawed, fresh-frozen cadaveric forequarter amputations were procured in conjunction with the US Army Combat Extremity Surgery Course.

Demographic data, including age, gender, and laterality were recorded. Each elbow was visually inspected for signs of previous trauma, surgery, or arthrofibrosis, which for our purposes was defined as range of motion <0 degree to 90 degrees. All diagnostic procedures were performed by a fellowship-trained orthopedic trauma surgeon.

Submitted for publication September 23, 2010.
Accepted for publication January 26, 2011.

From the Brooke Army Medical Center (T.F., D.S., K.K., J.R.H.), Fort Sam Houston, Texas; Ryder Trauma Center (J.K.), Miami, Florida.
Presented at the Society of Military Orthopaedic Surgeons Annual Meeting in December 19, 2009, Honolulu, Hawaii.
This study was approved by the Institutional Review Board of the Institute of Surgical Research at Brooke Army Medical Center, Fort Sam Houston, Texas.
This study was conducted under a protocol reviewed and approved by the Brooke Army Medical Center Institutional Review Board. The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.
Address for reprints: Todd Feathers, MD, 6967 Caribou Creek, San Antonio, TX 78244; email: toddfeathers@aol.com.

DOI: 10.1097/TA.0b013e3182127840

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 NOV 2011**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Effectiveness of the saline load test in diagnosis of traumatic elbow arthrotomies**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Feathers T., Stinner D., Kirk K., Kirby J., Hsu J. R.,**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

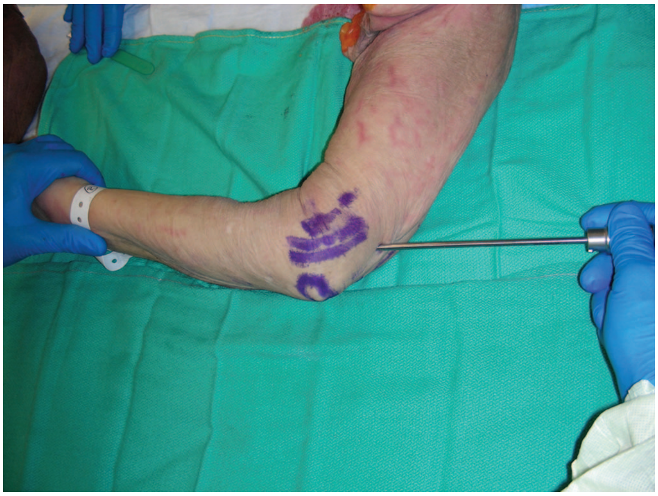

Figure 1. An arthrotomy was made through the posterocentral portal site with a 4.5-mm trochar.

Wound Creation

First, the elbow was placed in 90 degrees of flexion and neutral rotation, and an arthrotomy was made through a posterocentral portal site. A 1-cm longitudinal incision was made 3 cm proximal to the tip of the olecranon in the midline piercing the triceps at the musculotendinous junction. A 4.5-mm trochar was then used to bluntly dissect through the joint capsule, while aiming toward the posterior compartment of the elbow (Fig. 1). The elbow was then extended to verify intra-articular position by compression of the trochar between the olecranon and the olecranon fossa.

Static and Dynamic Elbow Saline Loading

To load the joint, a midlateral portal site was used with the elbow flexed to 90 degrees and the forearm pronated. The needle was inserted through the soft spot in the anconeus triangle, formed by the radial head, lateral epicondyle, and tip of the olecranon, aiming toward the antecubital fossa, penetrating only the anconeus and joint capsule.[11,12] Saline mixed with methylene blue (1 mg/300 mL concentration) was injected through an 18-gauge needle into the elbow joint capsule at a rate of 2 mL per second, until a volume of 20 mL was reached (Fig. 2). During the injection, the known arthrotomy site was observed for evidence of saline leakage. Any fluid leakage was considered a positive static load test. If no leakage was appreciated after injection of 20 mL, the elbow was taken through a range of motion from 0 degree to 90 degrees for five cycles or until leakage occurred. Any fluid leakage during the range of motion was considered a positive dynamic load test. The degree of flexion that the dynamic test became positive was measured.

Terminal Saline Loading

If still no fluid leakage occurred, the infusion continued with the joint in 90 degrees of flexion at a rate of 2 mL per second until fluid outflow occurred at the arthrotomy site. The total quantity of fluid injected at time of leakage was recorded. After each test was completed, the joint was grossly incised to verify intra-articular injection by visualizing methylene blue within the joint and staining of the articular cartilage (Fig. 3).

Figure 2. Methylene blue mixed with saline was injected through an 18-gauge needle at the midlateral portal site.

Figure 3. After each test was completed, the elbow joint was grossly incised to verify intra-articular injection by visualizing methylene blue within the joint and staining of the articular cartilage.

Statistical Methods

The test results and binomial variables of gender and laterality were compared using a Fisher's exact test. A nonparametric t test was used to compare the mean age of the elbows testing positive with those testing negative. Sensitivities with 95% confidence intervals were calculated for the static and dynamic tests. The volumes of fluid injected until leakage underwent logarithmic transformation and were used to produce

Test	Total Number of Elbow Tested	Number of Positive Tests	Sensitivity	95% Confidence Interval
Static Test	36	26	**72%**	58%-87%
Dynamic Test	36	31	**86%**	75%-97%

Figure 4. Results of static (without range of motion) and dynamic (with range of motion) tests.

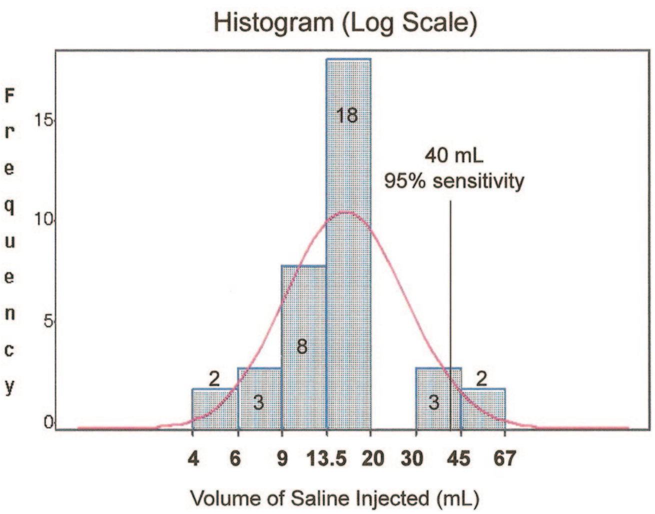

Figure 5. After logarithmic transformation, a normal distribution of elbows over the volume of saline injected to cause leakage. Infusion of 40 mL gave 95% sensitivity.

a normal distribution. This was used to calculate the injection volume necessary to reach a 95% sensitivity level.

RESULTS

None of the 40 elbows had evidence of previous trauma or surgery. Three elbows had previous cadaveric dissection that violated the joint capsule, and one elbow had evidence of significant arthrofibrosis, leaving 36 elbows for evaluation (14 female and 22 male; 19 left and 17 right; average age of 77 years).

Injection of 20 mL gave a positive result in 26 of the 36 elbows (static sensitivity, 72%; 95% confidence interval, 58–87%). Range of motion after the injection caused leakage in another 5 elbows (dynamic sensitivity, 86%; 95% confidence interval, 75–97%; Fig. 4). A total of 40 mL of injected fluid was required to identify 95% of the arthrotomies (Fig. 5). The average degree of flexion at which the dynamic test became positive was 44 degrees (range of 10–85 degrees). There was no association between gender, age, or laterality and a positive static or dynamic saline load test.

DISCUSSION

Periarticular lacerations with possible joint penetration are common injuries. The knee is the most frequently involved joint, followed by the elbow.[10] Orthopedic surgeons are often consulted to evaluate these injuries because of the concern for violation of the joint capsule. Unlike a superficial laceration that only requires local wound care, a laceration penetrating the joint capsule necessitates a more extensive debridement and irrigation to prevent acute septic arthritis. Marvel and Marsh reviewed 102 patients with 121 traumatic knee arthrotomies. They showed better results with open debridement and irrigation on the day of injury compared with delayed debridement and irrigation.[13] These results, showing better outcomes with early open debridement and irrigation of knee arthrotomies, have been extrapolated to other joints.

Previous studies have estimated the elbow joint volume to be 15 mL to 20 mL using arthrography.[7,8] In a cadaveric study, O'Driscoll et al.[9] found that the elbow joint capsule was palpably distended after injection of 15 mL to 20 mL of saline and determined the capacity of the elbow joint to be 23 mL ± 4 mL. In their examination of periarticular lacerations, Voit et al.[10] used a volume of 20 mL to perform the saline load test on the elbow. Some authors suggest loading the elbow until the joint becomes distended with increasing resistance to infusion or until the patient experiences significant discomfort.[4,5] This can be impractical when evaluating elbow lacerations in sedated patients or patients with head injuries. A standard injection volume of 20 mL for the static and dynamic saline load tests was used in this study.

Injection location can significantly affect the amount of fluid needed for a positive result, as shown recently by Nord et al.[14] in saline load testing of 56 knees with known arthrotomies. In our study, the arthrotomy was made at the posterocentral portal site with the elbow in 90 degrees of flexion as this was thought to be a common site and position of elbow injury. Lateral elbow injuries are also common; however, a lateral arthrotomy was not used because it was deemed by the authors to be too closed to the saline loading site.

Voit et al.,[10] in a study of 50 periarticular lacerations (including 4 involving the elbow), reported that a saline load test was far superior to clinical examination alone in determining joint penetration; however, they assumed 100% sensitivity with the saline load test.[10] A recent study by Tornetta et al. evaluated the effectiveness of the saline load test for the knee, using 80 knees in patients undergoing elective knee arthroscopy. A fixed volume of 60 mL of saline was injected while observing known operative arthrotomies for evidence of leakage at rest and then during passive range of motion. The data suggested a low sensitivity for detecting known small traumatic arthrotomy wounds (static, 36%; dynamic, 43%).[15] Moreover, using the elective arthroscopic knee model, Keese et al. performed saline load tests on 30 knees until fluid outflow was appreciated at the operative arthrotomy sites. They reported that a 50-mL injection successfully identified only 46% of known arthrotomies and that 194 mL was required to achieve 95% sensitivity.[3]

As previously described by Tornetta et al.[15] for the knee, a static followed by a dynamic saline load test at the standard elbow injection volume of 20 mL was used in our study. Our results showed the sensitivity of the static load test was 72% (95% confidence interval, 58–87%). With addition of the dynamic load test, the sensitivity was slightly improved to 86% (95% confidence interval, 75–97%). These sensitivities for the elbow were quite higher than those observed by Tornetta et al.[15] with respect to the knee (static, 36%; dynamic, 43%).

Similar to the study done by Keese et al. on the knee, we continued to infuse the elbows to identify the fluid volume necessary to obtain a 95% sensitivity.[3] Injection of 40 mL of fluid was required to identify 95% of the elbow arthrotomies. Although it may be impractical to load a conscious patient's elbow with 40 mL, because of significant discomfort, if 40 mL is used in an unconscious patient, a negative test strongly suggests that the laceration does not involve the joint.

This study had several limitations. First, we used cadaveric elbows, which do not exactly replicate the live elbows and joint tissue on which clinical saline load tests are performed. Moreover, the cadaveric elbows overly represent older, presumably less healthy specimens, than the typical trauma patient's elbow. The tissue in the cadaveric elbows may be less compliant, and the typical traumatic joint effusion is not present in the cadaveric elbows. Second, we only used one arthrotomy site. As it would be impossible to represent all potential elbow injury patterns, we felt the posterior arthrotomy site would be an appropriate model for a common traumatic injury. Third, our arthrotomy was small in size. However, these smaller arthrotomies are the injuries most likely to require a saline load test to determine joint violation, because larger wounds may be more obvious. Fourth, even though the injections were performed by a fellowship-trained orthopedic trauma surgeon, the injections may not all have been intra-articular. We confirmed intra-articular injection in all specimens by observing methylene blue staining of the joint cartilage in all the elbows after completion of the saline load.

In conclusion, this study shows that the saline load test can be a useful tool in helping determine whether a laceration near the elbow communicates with the joint. It is not an absolutely definitive test and should be used in conjunction with the clinical examination and radiographs to determine whether open surgical debridement and irrigation is indicated. In addition, the sensitivity of the saline load test can be increased with the addition of range of motion and injection of higher fluid volumes.

REFERENCES

1. Collins DN, Temple SD. Open joint injuries: classification and treatment. *Clin Orthop Relat Res.* 1989;243:48–56.
2. Siliski JM. Dislocations and soft tissue injuries of the knee: open knee injuries. In: Browner BD, Jupiter JB, Levine AM, Trafton PG, eds. *Skeletal Trauma*. 3rd ed. Philadelphia, PA: Saunders; 2003:439–471.
3. Keese GR, Boody AR, Wongworawat MD, et al. The accuracy of the saline load test in the diagnosis of traumatic knee arthrotomies. *J Orthop Trauma.* 2007;21:442–443.
4. Olson SA, Willis MD. Initial management of open fractures. In: Bucholz RW, Heckman JD, Court-Brown CM, eds. *Rockwood and Green's Fractures in Adults*. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2006:393.
5. Patzakis MJ, Dorr LD, Ivler D, Moore TM, Harvey JP Jr. The early management of open joint injuries: a prospective study of one hundred and forty patients. *J Bone Joint Surg Am.* 1975;57:1065–1070.
6. Raskind JR, Marder RA. Arthroscopic versus open debridement of penetrating knee joint injuries. *Iowa Orthop J.* 1993;13:121–123.
7. Hudson TM. Elbow arthrography. *Radiol Clin North Am.* 1981;19:227–241.
8. Johansson O. Capsular and ligament injuries of the elbow joint. A clinical and arthrographic study. *Acta Chir Scand*. 1962;suppl 287:1–159.
9. O'Driscoll S, Morrey B, Kai-Nan A. Intraarticular pressure and capacity of the elbow. *Arthroscopy.* 1990;6:100–103.
10. Voit GA, Irvine G, Beals RK. Saline load test for penetration of periarticular lacerations. *J Bone Joint Surg Br.* 1996;78:732–733.
11. Abboud JA, Ricchetti ET, Tjoumakaris F, Ramsey ML. Elbow arthroscopy: basic setup and portal placement. *J Am Acad Orthop Surg.* 2006;14:312–318.
12. Plancher KD, Shariff KB. Basics of elbow arthroscopy: setup, portals, and technique. *Tech Orthop.* 2006;21:239–249.
13. Marvel JE, Marsh HO. Management of penetrating injuries of the knee. *Clin Orthop Relat Res.* 1977;122:268–272.
14. Nord RM, Quach T, Walsh M, Pereira D, Tejwani NC. Detection of traumatic arthrotomy of the knee using the saline solution load test. *J Bone Joint Surg Am.* 2009;91:66–70.
15. Tornetta P III, Boes MT, Schepsis AA, Foster TE, Bhandari M, Garcia E. How effective is a saline arthrogram for wounds around the knee? *Clin Orthop Relat Res.* 2008;466:432–435.